Prisma Sains: Jurnal Pengkajian Ilmu dan Pembelajaran Matematika dan IPA IKIP Mataram
https://e-journal.undikma.ac.id/index.php/prismasains/index
e-mail: prismasains.pkpsm@gmail.com
April 2025. Vol. 13, No. 2
p-ISSN: 2338-4530
e-ISSN: 2540-7899
pp. 135-163

Fostering Higher-Order Thinking Skills in Mathematics Education: Strategies, Challenges, and Classroom Practices

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Received: March 2025; Revised: March 2025; Published: April 2025

Abstract

Despite increasing emphasis on Higher-Order Thinking Skills (HOTS) in mathematics curricula, classroom implementation remains limited and inconsistent. This qualitative study explored HOTS implementation in mathematics education, aimed to (1) identify effective instructional strategies for fostering HOTS, (2) examine teacher' challenges, and (3) analyze classroom practices. The study involved 25 stratified junior high school mathematics teachers, with data collected over one academic year through semi-structured interviews, classroom observations, and document analysis. Thematic analysis followed Braun and Clarke's six-phase framework.. The study highlights that an integrated instructional framework combining inquiry-based learning, collaborative practices, progressive learning support tailored to student needs, and technology significantly enhances higher-order thinking in mathematics. It demonstrates that aligning teacher beliefs, professional development, and systemic curricular support not only validates but also strengthens effective pedagogy for meeting the contemporary demands of critical thinking and problem-solving. Implementation is hindered by misalignment between curriculum goals and classroom realities, assessment practices, and theoretical professional development. Mathematics classrooms are progressively shifting toward critical problem-solving approaches, with teachers integrating analysis, evaluation, and creative tasks. Students demonstrate greater engagement with authentic tasks that connect to real-world contexts. These findings support the redesign of professional development programs and curriculum planning to enhance HOTS implementation in mathematics education.

Keywords: Higher-Order Thinking Skills; Instuctional Strategy; HOTS Practice; Mathematics Education; HOTS Challenges

How to Cite: Gradini, E., Firmansyah B, F., Noviani, J., & Ulya, K. (2025). Fostering Higher-Order Thinking Skills in Mathematics Education: Strategies, Challenges, and Classroom Practices. *Prisma Sains : Jurnal Pengkajian Ilmu dan Pembelajaran Matematika dan IPA IKIP Mataram, 13*(2), 135-163. doi:https://doi.org/10.33394/j-ps.v13i2.15099

https://doi.org/10.33394/j-ps.v13i2.15099

INTRODUCTION

In the rapidly evolving landscape of 21st-century education, the development of Higher-Order Thinking Skills (HOTS) has emerged as a cornerstone for fostering critical thinking, problem-solving, reasoning, and creativity. These skills are essential for success in today's knowledge-driven society. While global educational paradigms shift from rote memorization towards inquiry-based learning, empirical evidence from Indonesia's national assessment on Numeracy data reveals that only 23% of secondary students demonstrate proficiency in applying mathematical concepts to novel problems (Esti, Hersulastuti, Indiyah, & Kun, 2023).

This alarming statistic underscores the critical need to examine how mathematics education prepares students not only to perform calculations but also to engage deeply with complex problems.

Prominent frameworks such as the OECD's Programme for International Student Assessment (PISA) and the Trends in International Mathematics and Science Study (TIMSS) have underscored the pivotal role of HOTS in cultivating analytical and innovative competencies among learners. Recent PISA results indicate that students from countries emphasizing procedural fluency over conceptual understanding score significantly lower on items requiring mathematical reasoning and problem-solving (OECD, 2023). Despite numerous national education policies now emphasize the integration of HOTS into curricula, particularly within STEM disciplines, a striking disparity persists between the theoretical endorsement of HOTS and its practical implementation in classroom settings.

This study addresses a critical gap, which is the lack of empirically-grounded understanding of how HOTS principles translate into effective mathematics classroom practices. While theoretical frameworks abound, classroom-level implementation remains understudied, particularly the interplay between teacher perspectives, instructional strategies, and assessment approaches.

Recent research highlights that HOTS fosters a deeper understanding of mathematical concepts beyond rote memorization, enabling students to apply their knowledge to real-world scenarios. A systematic literature review by Kania & Kusumah emphasizes that assessing HOTS is crucial in determining students' ability to think critically and creatively (Kania & Kusumah, 2025). The study found that traditional assessments often fail to capture these skills, necessitating more advanced evaluation tools. Similarly, a study found that the Bridging Analogy Learning Model enhances students' problem-solving skills, highlighting the value of engaging teaching methods in fostering analytical thinking(Ansely, Rinaldi, & Putra, 2025). Studies have demonstrated that integrating STEM and HOTS through project-based learning enhanced vocational students' workforce readiness (Furqon, Riyanto, & Idris, 2025), while another found that open-ended HOTS questions improved creativity and mathematical reasoning in elementary students (Triyono, Subanji, & Arifin, 2025). Gender-based studies also reveal how different student groups approach HOTS-based problems, indicating the need for tailored teaching strategies (Khasanah, Alfisyahra, Pathuddin, & Lefrida, 2025). Furthermore, (Ndiung & Menggo, 2025) advocate for integrating ICT tools into HOTS assessments, promoting autonomy and deeper engagement in mathematics learning. These studies, while valuable, predominantly focus on isolated interventions rather than examining the systemic factors that enable or constrain HOTS implementation across diverse educational contexts.

The investigation of HOTS in mathematics education has grown significantly over three decades, evolving from peripheral interest to a central research focus. This evolution reflects a theoretical progression from viewing mathematical competence as procedural fluency to understanding it as a complex, socially-situated practice. Since Resnick (1992) highlighted its importance, scholarly attention has expanded alongside global policy shifts favoring competency-based curricula (OECD, 2018; UNESCO, 2019). The research trajectory includes three phases: initial conceptualization (1990-2005), focused on defining HOTS through cognitive psychology; empirical validation (2006-2015), emphasizing assessment tools and interventions; and implementation science (2016-present), exploring systemic factors affecting HOTS in diverse settings (Lithner, 2017; Schoenfeld, 2016).This evolution mirrors shifts from behaviorist to constructivist and sociocultural perspectives, recognizing HOTS as embedded in social, cultural, and institutional contexts (Rau, 2020; Rodriguez-barboza et al., 2025).

Addressing the Gap Through Novel Insights on HOTS

The literature on HOTS in mathematics education highlights recurring themes and limitations in conceptual frameworks, instructional strategies, teacher development, and assessment. While theoretical models have evolved from Bloom’s taxonomy to more nuanced frameworks emphasizing reasoning and problem-solving, they often remain disconnected from classroom practice (L.W Anderson et al., 2001; Anat Zohar, 2023). Research supports problem-based learning, inquiry-based instruction, and strategic questioning in fostering HOTS (Hmelo-Silver & Barrows, 2015; M. (Peg). Smith & Stein, 2018), yet idealized implementations overlook real classroom constraints. Studies recognize teacher beliefs and pedagogical knowledge as crucial (Hong & Cross Francis, 2020; Lloyd, 2024) but provide limited insights into how educators balance institutional, curricular, and assessment pressures. Moreover, assessment research reveals persistent misalignment between HOTS-focused instruction and evaluation (Rouffet, van Beuningen, & de Graaff, 2023; Schoenfeld, 2016). While formative assessment shows promise (Black & Wiliam, 2018), comprehensive frameworks for measuring mathematical HOTS remain underdeveloped.

This research addresses three critical gaps in the current literature: (1) the scarcity of empirical studies systematically identifying effective instructional strategies for HOTS integration; (2) limited examination of contextual challenges teachers face during implementation; and (3) insufficient triangulation of teacher perspectives, classroom observations, and instructional materials to comprehensively understand HOTS integration.

Despite the growing advocacy for HOTS in mathematics education, the literature reveals several critical gaps. First, there is a notable shortage of empirical studies that systematically identify and evaluate effective instructional strategies for HOTS integration. In addition, while educators are encouraged to implement HOTS-oriented instruction, current research seldom addresses the contextual and practical challenges teachers face when attempting to do so. Moreover, few investigations have embarked on systematic analyses of lesson plans and classroom practices to assess how thoroughly HOTS are being incorporated. These limitations underscore the need for a comprehensive study that bridges the gap between HOTS theory and classroom practice.

This study breaks new ground by addressing these deficiencies through several novel contributions. It is the first comprehensive investigation to triangulate teacher perspectives, classroom observations, and detailed lesson plan analysis to offer a holistic view of HOTS implementation in mathematics education. Furthermore, the study introduces an original analytical framework that quantitatively assesses the degree of HOTS integration, providing a more precise measure compared to past predominantly qualitative approaches. An additional innovative aspect is the exploration of the heretofore underexamined relationship between teacher epistemological beliefs about mathematics and their capacity to foster HOTS in students. Moreover, a new typology of instructional strategies specifically designed to promote HOTS in mathematics is advanced, moving beyond generic models of critical thinking. Finally, the study identifies context-specific barriers to effective HOTS implementation, extending the discussion beyond commonly cited constraints such as time and resources, thereby offering deeper insights into the challenges and potential solutions for teachers.

This study aims to address critical gaps in current understanding of HOTS implementation by pursuing three interconnected research objectives that together provide a comprehensive framework for examining how higher-order thinking skills are fostered in mathematics education. Particularly, this study’s objectives as follow.

The first objective is to identify instructional strategies used to promote HOTS in mathematics teaching. It include mathematics teachers' conceptual understanding and detailed analysis of strategies that effectively foster analytical, evaluative, and creative thinking in mathematics classrooms. The second objective is to examine challenges teachers face in implementing HOTS. The third objective is to analyze classroom practices and lesson plans to assess HOTS integration using an analytical framework.

The three objectives are deliberately interwoven to foster a holistic understanding of HOTS implementation. The identification of effective instructional strategies provides context for exploring implementation challenges, while the analysis of classroom practices evaluates how well these strategies manifest in practice. This integrated approach addresses the fragmentation evident in previous research, which has often examined these aspects in isolation.

This research contributes significantly to both theory and practice by bridging the documented gap between HOTS theoretical frameworks and classroom implementation. The findings offer actionable insights for teachers, policymakers, and curriculum designers, while advancing both the theoretical discourse and practical application of higher-order thinking in mathematics education.

Conceptualizations of HOTS in Mathematics Education

The conceptualization of HOTS in mathematics education embodies a rich theoretical plurality and evolving complexity. Early frameworks, predominantly grounded in adaptations of Bloom’s Taxonomy (Lorin W Anderson & Krathwohl, 2001; Bloom, Engelhart, Furst, Hill, & Krathwohl, 1956), provided initial heuristics by categorizing mathematical tasks according to cognitive demand. Despite their widespread influence, these hierarchical models have attracted criticism for their decontextualized treatment of mathematical processes and oversimplification of learning dynamics (Confrey, Maloney, Shah, & Belcher, 2019).

In response to these limitations, subsequent models such as the Structure of Observed Learning Outcomes (SOLO) Taxonomy (J. B. Biggs & Collis, 1982; J. Biggs & Tang, 2011) shifted the focus from task characteristics to the structural complexity of student responses. This reconceptualization recognizes that the manifestation of HOTS is not solely dependent on task design, but is intrinsically linked to how students engage with and internalize mathematical content. Concurrently, the Mathematical Proficiency model (Findell, Swafford, & Kilpatrick, 2001) introduced a multidimensional framework that integrates conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, and productive disposition, thus accounting for both cognitive processes and dispositional factors inherent in mathematical thinking.

More recent frameworks have further refined these perspectives by incorporating domain-specific nuances. For instance, Schoenfeld’s model of mathematical problem-solving emphasizes the critical roles of metacognition, beliefs, and mathematical practices in fostering HOTS (Schoenfeld, 2016). Similarly, Lithner’s dichotomy between creative and imitative reasoning delineates a clear distinction between algorithmic application and novel solution construction, offering a nuanced tool for assessing the quality of mathematical thought (Lithner, 2017).

Cross-cultural investigations reveal that the conceptualization of HOTS is deeply embedded in broader educational philosophies. East Asian models, which often highlight the integration of procedural fluency and conceptual understanding (Cai & Hwang, 2020), contrast sharply with Western approaches that tend to separate these domains (Rittle-Johnson & Schneider, 2015). These cultural variations underscore the influence of societal values on educational methodologies and highlight the need for contextually sensitive frameworks.

Despite these theoretical advancements, several critical gaps remain. Most frameworks continue to underemphasize the domain-specific characteristics of mathematical thinking by applying generic cognitive taxonomies that inadequately address the intricacies of mathematical processes. Moreover, an overemphasis on cognitive aspects often sidelines important social, emotional, and cultural dimensions of learning (Gutiérrez, 2013). A further limitation is the persistent disconnect between sophisticated theoretical models and their practical applicability in classroom settings (Samone, 2024), which calls for more actionable, practice-oriented approaches. Additionally, the scarcity of culturally responsive models, which incorporate diverse knowledge systems and traditions (Safirah, Nasution, & Dewi, 2024), along with the static nature of most taxonomies that overlook developmental trajectories across educational levels, presents an ongoing challenge for curriculum and assessment design.

Instructional Strategies for Promoting HOTS

The literature demonstrates that specific pedagogical approaches significantly enhance mathematical reasoning and complex problem-solving capabilities. Problem-based learning (PBL) has emerged as particularly effective for developing HOTS, with studies by (Hmelo-Silver & Barrows, 2015) and (Schoenfeld, 2016) documenting how structured engagement with complex problems enhances students' analytical capabilities and metacognitive awareness. However, the efficacy of PBL is contingent upon implementation quality, requiring careful design and facilitation (Aba-Oli, Koyas, & Husen, 2024; Parwata, Jayanta, & Widiana, 2023).

Inquiry-based instruction similarly fosters mathematical HOTS, with empirical evidence from (Abdurrahman, Halim, & Sharifah, 2021) and (Lazonder & Harmsen, 2016) revealing significant positive effects on critical thinking development. Nevertheless, research has yet to fully delineate which specific components of inquiry-based approaches yield the most substantial benefits. The strategic deployment of questioning techniques represents another crucial dimension, with (M. (Peg). Smith & Stein, 2018) establishing that cognitively demanding questions elevate mathematical discourse and conceptual understanding, though Boaler and Staples observe that many educators default to lower-level questioning patterns that fail to stimulate deeper cognitive processing (Boaler & Staples, 2022).

Shulman's Pedagogical Content Knowledge (PCK) framework provides a theoretical foundation for understanding how the integration of subject expertise with pedagogical strategies fosters problem-solving and critical thinking. Effective mathematics instruction transcends content delivery to encompass the deliberate construction of learning experiences that promote inquiry, challenge preconceptions, and cultivate analytical competencies. Teachers with robust PCK strategically select instructional methods that guide students toward critical exploration and real-world application of mathematical concepts, thereby facilitating the transition from procedural fluency to higher-order reasoning (Abdullah et al., 2016; Gudmundsdottir & Shulman, 1987; Sa'dijah, Murtafiah, Anwar, & Sa'diyah, 2023; Wakhidah, Juhaeni, Safaruddin, Erman, & Lodhi, 2025). Through this lens, mathematics education becomes a process of intellectual empowerment, equipping students with the cognitive tools to reason, evaluate, and address complex challenges.

Technological interventions, particularly dynamic mathematics software, have demonstrated potential for supporting HOTS development (Ji, Guo, & Song, 2024). However, many studies in this domain insufficiently account for the broader instructional context in which these tools are deployed. The research landscape in HOTS development faces methodological challenges, including limited sample sizes, inadequate control conditions, and assessment validity concerns. A significant gap persists in understanding how teachers adapt HOTS-oriented strategies across diverse classroom environments, a critical factor affecting implementation fidelity and, consequently, instructional effectiveness.

Teacher Challenges and Professional Development

Implementing instructional strategies that foster HOTS in mathematics presents significant challenges. Research identifies several critical barriers, including teachers' struggles to construct cognitively demanding tasks, facilitate effective mathematical discourse, and offer sufficient scaffolding without reducing cognitive demand (Hamzah, Hamzah, & Zulkifli, 2022; Leighton, 2017). Furthermore, educators' underlying beliefs about mathematics, whether viewed as a set of procedures or as a domain of conceptual understanding, play a pivotal role in shaping their pedagogical choices. Empirical studies reveal that teachers who regard mathematics as a fixed body of knowledge are less inclined to implement strategies that encourage higher-order thinking (Lloyd, 2024; Pocalana & Robutti, 2024). These entrenched belief systems often resist transformation, even in the presence of targeted professional development initiatives (R. Li, Cevikbas, & Kaiser, 2024).

While professional development models show potential for enhancing teachers' abilities to recognize and promote higher-order thinking, many of these initiatives suffer from a lack of sustained engagement and contextual relevance, thereby limiting their impact on classroom practices (Desimone & Garet, 2015; Erumit, Ozmen, & Cebeci, 2025; Follmer, Groth, Bergner, & Weaver, 2023; Hourigan & Leavy, 2024; Lalrinawma & Lalchhandami, 2024; van Es & Sherin, 2021). Moreover, there is a pronounced research gap regarding the specific challenges faced in diverse educational settings, notably in under-resourced schools or culturally heterogeneous environments (Murray & Milner, 2015). Consequently, further investigation is warranted to develop sustainable, scalable professional development frameworks that can be tailored to varied institutional contexts while ensuring both fidelity and effectiveness.

Assessment of HOTS in Mathematics

The assessment of Higher-Order Thinking Skills (HOTS) in mathematics presents intricate challenges that surpass traditional evaluation methods. Research on HOTS assessment tools underscores significant limitations in capturing the multidimensional and integrated nature of advanced mathematical reasoning. Several studies reveal a persistent misalignment among curriculum, instruction, and assessment, with documented discrepancies indicating that while curricular objectives emphasize HOTS, assessment practices predominantly gauge procedural fluency (Darling-Hammond & Adamson, 2014; Ismail, Retnawati, Arovah, & Imawan, 2024; Rouffet et al., 2023; Wilson & Narasuman, 2020; Anat Zohar, 2023). Furthermore, even in instances where HOTS-focused instruction is implemented, summative assessments tend to revert to lower-level cognitive demands, fostering an environment of instructional dissonance (Schoenfeld, 2016).

Conversely, research into formative assessment practices offers promising avenues for supporting HOTS development. Evidence indicates that strategic questioning, peer assessment, and self-reflection can effectively scaffold higher-order cognitive processes (Black & Wiliam, 2018), while iterative formative assessment cycles provide continuous opportunities for students to refine complex mathematical reasoning (Wiliam & Thompson, 2017). Despite these advances, prevailing assessment frameworks still exhibit notable deficiencies. Many existing instruments fragment complex thinking into discrete, measurable components, thereby failing to capture the holistic and dynamic progression of mathematical reasoning (Brookhart, 2014). Moreover, these tools often overlook the socially constructed dimensions of mathematical knowledge, particularly the roles of collaborative problem-solving and communal knowledge-building (Krogman, 2022).

In response, there is a critical need for the development of more authentic and comprehensive assessment methodologies that accurately reflect the dynamic, non-linear nature of higher-order thinking. Future research should aim to devise frameworks that balance practical utility in classroom settings with the capacity to recognize diverse manifestations of mathematical reasoning across varying cultural and linguistic contexts (Zhou, Ning, Chen, Zhang, & Wijaya, 2024).

The integration of Schoenfeld, Lithner, and Resnick's theoretical frameworks with classroom realities reveals a critical gap between idealized cognitive development models and actual instructional practices. This disconnect, exacerbated by assessment constraints, limited professional development, and traditional teaching approaches, creates an environment where higher-order thinking skills remain underdeveloped despite their recognized importance. This integration bridging the gap by examining how these theories can be effectively implemented in diverse educational settings, ultimately developing practical frameworks that honor theoretical principles while addressing real-world teaching challenges.

METHOD

Research Design

This study employed a qualitative research approach to investigate the implementation of HOTS in mathematics education. This methodological choice allowed for an in-depth exploration of teaching practices and contextual factors influencing HOTS integration in mathematics classrooms, following a case study approach (Creswell & Poth, 2016; Merriam, 2015; Yin, 2017). The research design was specifically aligned with three primary objectives: (1) identifying effective instructional strategies that promote HOTS, (2) examining challenges teachers face in implementation, and (3) analyzing classroom practices for evidence of higher-order thinking.

Participants and Sampling

The study included 25 mathematics teachers from junior high schools in Mathematics Teacher Working Group (*Musyawarah Guru Mata Pelajaran*, MGMP). The sample was stratified to ensure representation of urban, suburban, and rural schools, as well as varying levels of resources and student demographics. Participants had teaching experience ranging from 3 to 30 years (Mean= ± 17.84 years, SD= ± 8.10 year) and taught grades 7-9. The majority of participants (80%) held Bachelor's degrees, while 20% had Magister degrees. Selection criteria included: (1) At least three years of mathematics teaching experience; (2) Current teaching assignment in grades 7-9; (3) Membership in the Mathematics Teacher Working Group (MGMP); and (4) Willingness to participate in all phases of the research

Maximum variation sampling was employed to ensure diversity in educational contexts, teaching experience, and exposure to HOTS implementation. This sampling strategy allowed for the identification of both common patterns and unique variations in how teachers conceptualize and implement higher-order thinking skills in mathematics education across different contexts.

Table 1. Demographic Characteristics of Participating Mathematics Teachers

Characteristic	n (%) or Mean ± SD
Gender	Female: 15 (60.00%)
	Male: 10 (40.00%)
School Location	Urban: 13 (52.00%)
	Suburban: 8 (32.00%)
	Rural: 4 (16.00%)
Education Level	Bachelor's: 20 (80.00%)
	Magister: 5 (20.00%)
School Resource Level	High: 11 (44.00%)
	Medium: 11 (44.00%)
	Low: 3 (12.00%)
Teaching Experience	Range: 3-30 years
	Mean ± SD: 17.84 years ± 8.10 years
	Early Career (3-5 years): 12.00%
	Developing (6-10 years): 16.00%
	Experienced (11-20 years): 60.00%
	Veteran (>21 years): 12.00%
HOTS Implementation Experience	Range: 0-10 years
	Mean ± SD: 4.88 years ± 3.24 years
Professional Development Hours (last 2 years)	Range: 0-98 hours
	Mean ± SD: 44.60 hours ± 32.29 hours
Average Class Size	Range: 20-39 students
	Mean ± SD: 29.76 students ± 6.76 students
Grade Levels Taught	Grade 7: 36.00%
	Grade 8: 36.00%
	Grade 9: 28.00%

The demographic data reflects the maximum variation sampling strategy employed in this study. As shown in Table 1, participants represented diverse educational contexts, with varying levels of teaching experience, educational backgrounds, and exposure to HOTS implementation. This diversity allowed for the identification of both common patterns and unique variations in how teachers conceptualize and implement higher-order thinking skills in mathematics education across different contexts.

The teacher coding scheme employs a systematic alphanumeric format that efficiently captures key demographic information for 25 mathematics teachers participating in the research study. Each teacher is assigned a unique identifier (T01-T25) followed by a detailed code that encapsulates critical variables. Teaching experience level denoted by the first letter: E for Early Career, D for Developing, E for Experienced, V for Veteran, followed by specific years of teaching experience (ranging from 3-30 years), grade level taught (7, 8, or 9), and gender (F or M). For example, the code "T05-V22-9-F" represents Teacher #5, a Veteran teacher with 22 years of experience, teaching Grade 9, who is Female.

Data Collection

Data collection occurred over one academic year using multiple methods to ensure methodological triangulation, as follow.

Semi-structured Interviews

In-depth interviews were conducted with all 25 participating teachers. The interview protocol focused on teachers' understanding of HOTS, their instructional strategies for promoting higher-order thinking, perceived challenges in implementation, and their assessment approaches. Each interview lasted approximately 20-30 minutes and was audio-recorded for subsequent transcription and analysis.

Table 2. Questions of Semi-structure Interviews

Section	Questions
Understanding of HOTS	1. How would you define Higher-Order Thinking Skills (HOTS), and why do you think they are important in education? 2. How familiar are you with Bloom's Taxonomy, and how does it guide your understanding of HOTS?
Instructional Strategies	3. Can you describe one or two strategies you use to promote HOTS in your classroom? 4. Could you share an example of a specific activity or lesson that you believe effectively promotes HOTS?
Challenges in Implementation	5. What challenges do you face when trying to implement HOTS in your teaching practice? 6. How do you address these challenges?
Assessment Approaches	7. How do you assess whether your students are developing HOTS? 8. What types of assessment tools or methods do you use to evaluate students' ability to analyze, evaluate, and create?

Classroom Observations

A total of 25 teachers were selected for classroom observations, with each teacher being observed three times throughout one academic year. These observations followed a structured protocol designed to examine various aspects of instructional practices, including the types of questions posed by teachers, categorized according to Bloom's taxonomy, the nature of tasks assigned, classroom discourse patterns, student engagement with higher-order thinking activities, and teacher responses to student thinking. The observation protocol utilized a validated rubric adapted from Marzano's teacher evaluation model (Marzano, 2013) and Smith and Stein's cognitive demand framework (M. S. Smith & Stein, 1998). Specific indicators included: (1) frequency and quality of higher-order questions based on Bloom's taxonomy levels of analyzing, evaluating, and creating; (2) cognitive demand level of mathematical tasks using Smith and Stein's four-level classification; (3) wait time after posing higher-order questions; (4) teacher scaffolding techniques; and (5) student reasoning opportunities measured by instances of explanation, justification, and mathematical argumentation. Each indicator was rated on a 5-point Likert scale with descriptive benchmarks for each level.

Document Analysis

Lesson plans, assessment materials, and student work samples were collected from participating teachers. These documents were analyzed using a systematic content analysis approach (Bowen, 2009) to identify the planned integration of HOTS and evidence of student engagement with higher-order thinking. The analysis employed a rubric adapted from Anderson and Krathwohl's revised Bloom's Taxonomy framework (Lorin W Anderson et al., 2001), which provided specific indicators for each cognitive level. Documents were coded according to four main criteria: cognitive demand level (categorizing tasks as lower-order or higher-order based on required cognitive processes), task complexity (assessed on a three-point scale based on cognitive steps and conceptual connections), open-endedness (evaluating problems for multiple solution paths or interpretations), and evidence of student reasoning (examining work samples for demonstrations of analytical, evaluative, and creative thinking). To ensure reliability, two researchers independently coded 20% of the documents, establishing strong inter-rater reliability (Cohen's $\kappa = 0.84$) before completing the full analysis, with discrepancies resolved through discussion until consensus was reached.

Data Analysis

The qualitative data underwent thematic analysis following Braun and Clarke's (2006) six-phase approach. This process began with familiarization through repeated reading of the data, followed by the generation of initial codes related to the implementation of HOTS. The researchers then searched for patterns among the codes, reviewed emerging themes for coherence and distinctiveness, and refined them by defining and naming key themes. The final stage involved synthesizing these insights into a comprehensive analysis.

The thematic analysis specifically aimed to identify effective instructional strategies that foster HOTS, challenges encountered in implementing these strategies, and concrete evidence of higher-order thinking in classroom practices. These findings directly addressed the study's primary objectives, providing valuable insights into the pedagogical approaches that support the development of students' critical and analytical thinking skills.

To ensure the rigor of the analysis, initial coding was conducted independently by researchers, after which codes and themes were collaboratively refined. Python software was utilized to support our thematic analysis process in two distinct ways: first, for data organization and management (including sorting, categorizing, and retrieving text segments), and second, for pattern identification through frequency analysis of recurring concepts. Specifically, we employed the pandas library for data structuring and NLTK for basic text processing, while the interpretive analytical work remained primarily manual This hybrid approach allowed us to systematically process large volumes of qualitative data while maintaining interpretive depth. Additionally, member checking was conducted with a subset of participants to enhance the trustworthiness and credibility of the interpretations.

Ethical Considerations

The research adhered to established ethical guidelines for educational research. Informed consent was secured from all participants, with clear explanations of the research purpose, procedures, and confidentiality measures. Pseudonyms were used for all participants and schools to protect anonymity. Participants were informed of their right to withdraw at any stage without consequences.

RESULTS AND DISCUSSION

Teacher interviews revealed that HOTS involves critical thinking, problem-solving, and creativity to tackle real-world challenges. Bloom's Taxonomy was identified as a guiding framework for designing lessons targeting higher cognitive levels. Teachers emphasized equipping students with analytical tools for effective problem-solving.

As instructional approaches, teachers employed Socratic questioning, problem-based learning, and collaborative discussions. Effective activities included primary source analysis, real-world problem-solving, and group discussions. For assessment, teachers utilized formative assessments, problem-solving tasks, and performance-based evaluations, with concept maps, think-aloud sessions, and digital storytelling projects supporting HOTS evaluation. Despite strong HOTS understanding, teachers encountered implementation challenges including time constraints, professional development gaps, and difficulties designing authentic assessments. These were addressed through collaborative group work, balanced test preparation, and clearer instructional structures.

Classroom observations confirmed teachers' use of questioning techniques for analysis and evaluation tasks. Group discussions and problem-solving exercises fostered collaboration and critical thinking, though some lessons lacked sufficient scaffolding for higher cognitive engagement. Curriculum documents aligned with Bloom's Taxonomy, emphasizing analysis, evaluation, and creation. Assessment rubrics included critical thinking criteria but often lacked detailed creativity evaluation guidelines. Lesson plans demonstrated HOTS focus, with some implementation inconsistencies across subjects.

These findings comprehensively address the research questions by identifying HOTS promotion strategies, implementation challenges, and assessment approaches across multiple data sources.

Theme 1. Instructional Strategies Promoting HOTS

Our thematic analysis revealed four key strategies for fostering HOTS in mathematics education (Fogure 1). Innovative Questioning promotes deep thinking through open-ended problems with real-world applications. Collaborative Learning develops critical analysis through structured group work and peer teaching. Technology Integration makes abstract concepts tangible through interactive tools. Context-Sensitive Scaffolding personalizes learning through differentiated instruction. These interconnected strategies form a holistic framework for developing higher-order thinking skills.

The findings from classroom observations, interviews, and document analysis in theme 1 is an alignment with research objective 1, identifying effective instructional strategies. These analysis provide a detailed understanding of how instructional strategies are employed to foster HOTS in mathematics education.

Observations in grades 7-9 mathematics classrooms revealed teachers systematically promoting higher-order thinking through specific instructional strategies. In a grade 8 algebra lesson, teachers used open-ended questioning ("*How else might you approach this problem*?" [T21-E5-7-M]) and and structured collaborative problem-solving activities that engaged students in analysis beyond mere computation. Additonally, a classroom note stated, "*The teacher's use of collaborative problem-solving allowed students to move beyond computation, engaging in deep analysis and creative solution strategies*." Lesson plans and curriculum documents explicitly incorporated inquiry-based learning and scaffolded problem-solving to develop HOTS, designing tasks that required students to analyze, synthesize, and evaluate novel mathematical scenarios rather than simply practice procedures.

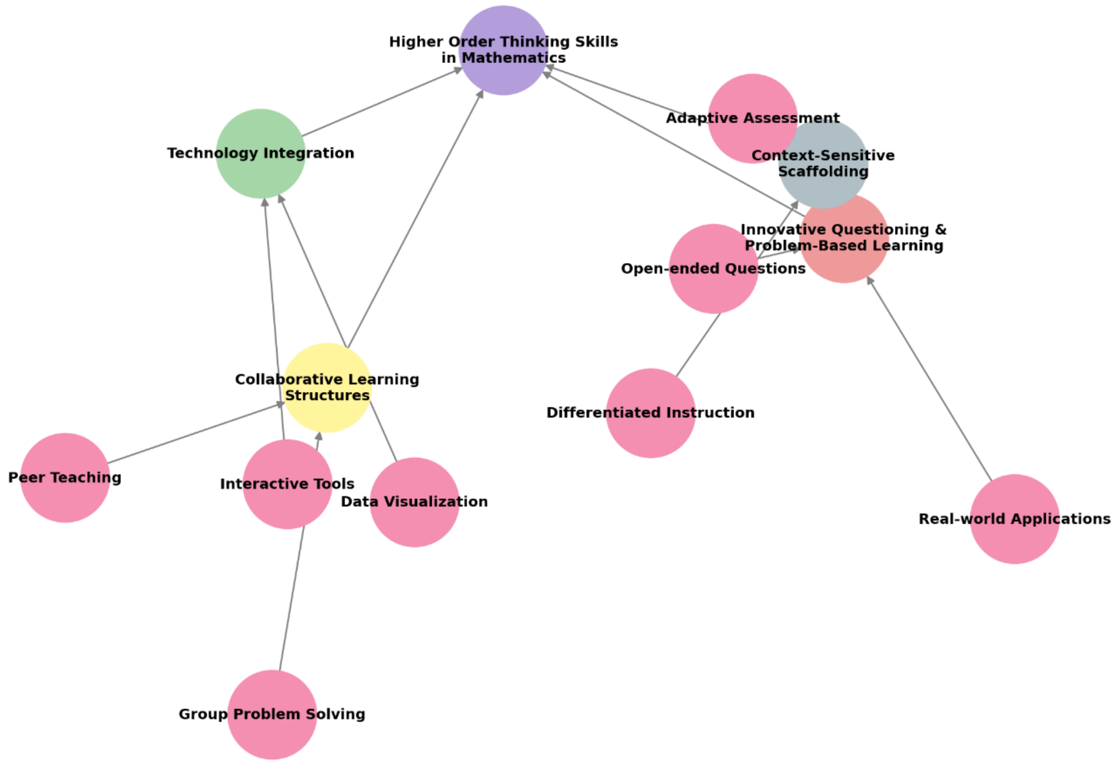

Figure 1. Thematic Diagram of Instructional Strategies Promoting HOTS

Mathematics teachers (experience: 3-30 years) consistently adopted innovative strategies to promote HOTS, balancing direct instruction with independent thinking opportunities. They emphasized real-world application problems as particularly effective for connecting abstract concepts to everyday contexts.

"*I incorporate problem-based learning in my class. I used PBL because it is not only engaged students in critical thinking Miss, but also gives them a context for why these skills matter beyond the classroom, in their real life*." (T04-E15-8-F)

"*Using technology, such as interactive student worksheet, has really transformed the way my students approach difficult concepts. They were able to make abstract ideas more tangible*." (T17-E20-8-M)

Data revealed three key strategies for promoting HOTS: open questioning techniques that required reasoning justification, collaborative learning that facilitated peer problem-solving, and technology integration that visualized abstract concepts. One veteran teacher (T05-V22-9-F) noted that transitioning from procedural teaching to discussion-based approaches marked "*a turning point in how my students learned to think mathematically*."

Curriculum demands drove teachers to integrate HOTS while covering required content. They achieved this balance through problem-based learning, open questioning, and technology integration. These approaches simultaneously addressed syllabus requirements and deepened cognitive engagement.

Teaching experience significantly influenced strategy selection. Early-career teachers typically followed structured guidelines to ensure curriculum compliance, while veterans demonstrated greater pedagogical flexibility and innovation in HOTS implementation. This pattern highlights how professional experience fosters instructional adaptability.

Another critical influence is the experiential diversity among teachers. Teaching experience significantly shaped HOTS implementation strategies. Early-career teachers typically adhered to structured guidelines and prescribed methods to ensure curriculum compliance. In contrast, veteran teachers demonstrated greater flexibility, experimenting with innovative approaches that effectively fostered higher-order thinking.

Real-world relevance emerged as another critical factor driving instructional choices. Classroom observations confirmed that connecting mathematical concepts to practical applications significantly increased student engagement and facilitated deeper cognitive processing, specifically the analysis, evaluation, and creation skills central to HOTS development.

The findings from teacher's interviews, classroom observations, and documents analysis advance our understanding of instructional strategies in mathematics education by elucidating both the micro-level classroom practices and the macro-level curricular influences that collectively foster HOTS. The data reflect a paradigm shift from traditional procedural teaching toward an enriched educational framework that emphasizes inquiry-based learning, collaborative problem-solving, technology integration, and context-sensitive scaffolding. Such a shift is catalyzed by the evolving demands of the modern workforce, which prioritizes critical thinking and analytical competencies over rote computation. Consequently, teachers are increasingly compelled to design learning experiences that not only adhere to content standards but also cultivate deeper cognitive engagement.

Integral to these developments are the teacher beliefs and professional trajectories documented in the study. Veteran teachers have exhibited a marked willingness to transcend conventional instructional boundaries, signaling a professional maturation. For instance, the transformation described by experienced teachers, moving from a strictly procedural focus to an approach that values reflective discussions, underscores the significance of teacher in fostering HOTS. Concurrently, early-career teachers, while more reliant on prescribed methods, are gradually integrating these emergent strategies under the guidance of curriculum reforms and structured pedagogical frameworks. This dual influence of experience and institutional support suggests a confluence of factors that bolster the systematic adoption of higher-order thinking pedagogy.

The curricular evaluation further reinforces these findings by demonstrating a deliberate alignment between instructional guides and HOTS development initiatives. The explicit recommendations in curriculum documents reflect an authoritative response to the longstanding challenge of balancing content delivery with cognitive development. This curricular orientation echoes established literature, including Shulman's frameworks on pedagogical content knowledge (Abdullah et al., 2016; Gudmundsdottir & Shulman, 1987; Sa'dijah et al., 2023; Wakhidah et al., 2025), and resonates with Hattie's emphasis on visible learning strategies (Hattie, 2012). The present findings also align with research that underscores the efficacy of real-world problem contexts in enhancing both student engagement and critical thinking (Halpern & Dunn, 2021; Mebert et al., 2020), thereby validating the interconnected strategy framework.

However, one notable deviation in our findings is the varied adaptation based on teacher experience. While most of the literature emphasizes a one-size-fits-all approach to professional development for HOTS (de Jong et al., 2023), our data suggests that veteran teachers often tailor techniques to the nuanced needs of their students better than early career teachers. This indicates that future research and professional development programs might benefit from differentiated training modules that account for varying levels of teaching experience.

The implications for mathematics teaching and learning are profound. Theoretically, the integration of diverse yet interrelated instructional strategies offers a robust model that not only extends existing constructivist frameworks but also operationalizes them in response to modern educational imperatives. Empirically, the data suggest that when teachers employ a balanced blend of innovative questioning, collaborative structures, technological tools, and adaptive scaffolding, they achieve measurable improvements in student cognitive engagement and problem-solving proficiency. Practically, this research provides compelling evidence for reorienting teacher training, curriculum design, and classroom practices toward a more holistic approach that emphasizes higher-order thinking. In this regard, the findings call for a reexamination of educational policies to support and sustain these innovative practices, ensuring that mathematics education evolves in tandem with the demands of a rapidly changing world.

Theme 2. Challenges in Implementing HOTS

Figure 2 illustrates the complex challenges educators face when implementing HOTS in mathematics classroom. The thematic map reveals five interconnected challenge categories: Time Constraints & Curriculum Pressure, Student Readiness & Skill Gaps, Resource & Support Limitations, Assessment Challenges, and Professional Development Deficiencies. Time constraints, exacerbated by rigid pacing requirements and standardized testing pressures, directly impact teachers' ability to develop the deeper learning experiences HOTS requires. This challenge is compounded by student readiness issues, where varied mathematical backgrounds and resistance to open-ended problem-solving create implementation barriers.

The remaining three challenge categories represent systemic obstacles that require institutional intervention. Resource limitations (including inadequate technology access and instructional materials) hamper effective HOTS implementation, while assessment challenges highlight the difficulty of evaluating higher-order thinking through traditional testing methods. Professional development deficiencies, particularly the lack of subject-specific strategies and insufficient training opportunities, further undermine teachers' capacity to effectively integrate HOTS. This thematic map demonstrates that successful HOTS implementation requires a multi-faceted approach addressing both classroom-level challenges and broader systemic barriers within educational institutions.

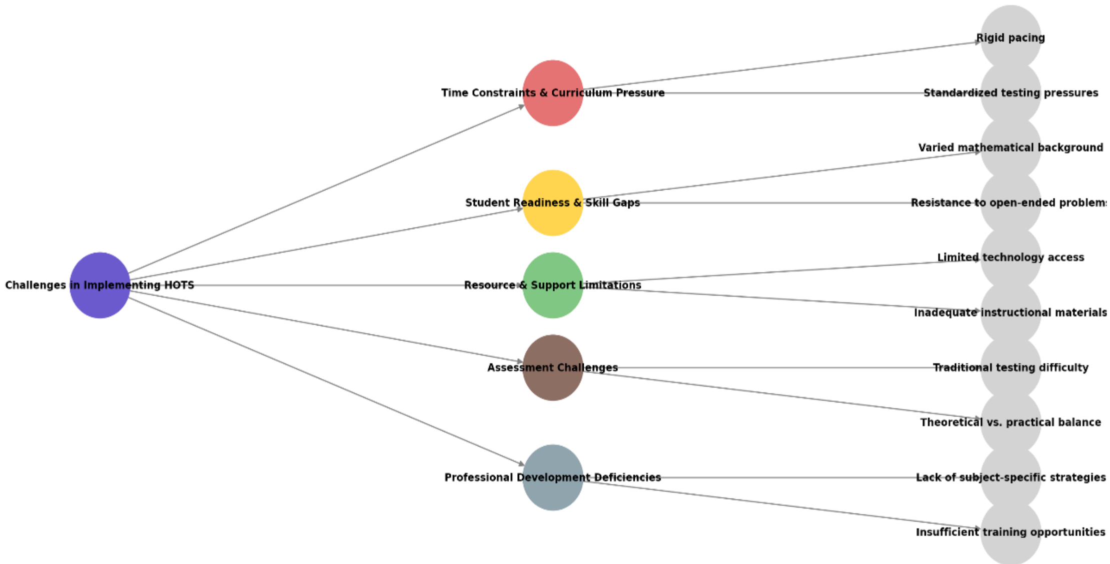

Figure 2. Thematic Diagram of Challenges in Implementing HOTS

The findings from classroom observations, interviews, and document analysis in theme 2 is an alignment with research objective 2, identifying challenges in implementing HOTS. Teacher interviews reveal five common challenges in implementing HOTS in mathematics classroom. Firstly, time constraints and curriculum pressure. Teachers consistently reported that limited instructional time is a central challenge. Many expressed that a rigid curriculum schedule forces them to cover an extensive range of topics, leaving little opportunity for deeper inquiry. For example, one teacher stated:

"I often feel squeezed by the curriculum. Even though I want to explore a topic deeply with my students, I had to rush through lessons just to cover all the required content." (T08-E14-8-M)

Another mentioned having to balance test preparation with authentic learning experiences, indicating that the pressure to meet standardized milestones undermines the potential for engaging HOTS activities.

Secondly, student readiness and skill gaps**.** A recurring theme in the interviews was the significant variation in student preparedness. Several teachers noted that while a segment of their class is ready to engage in open-ended, analytical tasks, others remain dependent on direct instruction and are reluctant to deviate from seeking 'the right answer.' One participant remarked,

"Many of my students are not used to thinking critically; they expect clear-cut answers. This gap often forces me to simplify tasks, which dilutes the purpose of HOTS." (T21-E5-7-M)

Thirdly, limited resources and support. Interviewees also brought up the issue of inadequate support in terms of resources. Teachers described struggles such as limited access to digital tools, multimedia resources, and subject-specific materials. One teacher highlighted that

"The available resources are outdated, and without proper tools, it is difficult to create HOTS tasks." (T09-E13-7-F)

Additionally, there was a prevailing sentiment among educators that professional development opportunities lacked a specific focus on practical strategies for implementing HOTS in the classroom. Many teachers expressed frustration that existing training programs remained too theoretical, offering broad discussions on the importance of HOTS without providing concrete, actionable methods to integrate these skills into daily instruction.

"We keep hearing about the importance of HOTS, the theory, hmmm ... the training we receive is too theoretical. We need real, practical strategies that we can apply in our classrooms tomorrow." (T22-E15-9-F)

As a result, educators felt unprepared to effectively foster critical thinking, problem-solving, and analytical reasoning among their students. This gap in professional development highlights the need for targeted workshops, hands-on training sessions, and resource-sharing platforms that equip teachers with practical tools to enhance student engagement and cognitive development.

Finally, assessment difficulties. The interviews revealed difficulty in aligning traditional assessment methods with the goals of higher-order thinking. Teachers found it daunting to design assessments that measure complex cognitive skills. A teacher explained,

"Our assessments focus on one right answer, which directly conflicts with the nature of HOTS. Designing alternative assessments that truly capture deep thinking becomes an uphill battle." (T02-E14-7-F)

"In our school, assessments should be in multiple choice. I can not test the HOTS in multiple choice question." (T19-V22-8-F)

Meanwhile, the findings of classroom observations elucidate the challenges in implementing HOTS, such as: (1) Classroom dynamic and interaction, (2) Technology limitation, and (3) Teacher Adaptation Strategies. Observations in various classrooms indicate that despite teachers' best intentions, HOTS activities are often constrained by classroom dynamics. In many sessions, the structure of the lesson is tightly controlled by the need to adhere to a strict schedule. Observers noted that during HOTS-related tasks, only approximately 40% of students actively engaged in activities such as group discussions or problem-solving tasks. The rest of the class appeared hesitant, often waiting for cues from more confident peers.

Furthermore, observational notes revealed that classrooms with limited technological support often showed visibly truncated HOTS sessions. For instance, in one class, the intended discussion on multiple problem-solving strategies had to be cut short when the teacher needed to move on to the next topic. In contrast, classes equipped with more resources displayed richer discussions, although they too were not immune to timing issues.

Additionally, teachers were observed to implement quick, adaptive measures to compensate for their limitations. In several instances, teachers resorted to informal grouping to stimulate peer support or integrated brief reflective sessions to ensure that even a short discussion could yield some critical thinking benefits. However, these adaptations were often described as “stopgap measures” that did not fully address the underlying systemic issues causing the challenges.

An analysis of curriculum documents and lesson plans revealed that while the overall framework emphasizes higher-order thinking objectives, the actual lesson plans rarely allocate sufficient time for in-depth inquiry. Most lesson plans are densely packed with content coverage targets, leaving very limited windows to engage students in analysis, synthesis, and evaluation. This structural design continues to place teachers in a predicament, where the intent for HOTS is theoretically present but practically unsustainable.

A review of textbooks and supplementary materials uncovered a predominant focus on factual recall and basic understanding. Only about 25%-30% of the items in these resources prompted students to engage in higher-order queries. This misalignment between the theoretical goals of HOTS and the face-value content of textbook materials directly contributes to the difficulty of adequately preparing both teachers and students for more complex problem-solving tasks.

Documents related to teacher training and professional development showed that while several sessions on HOTS are offered, they tend to be generic and theoretical. There is a notable absence of hands-on, subject-specific strategies that align with real classroom challenges. Data from these documents suggested that less than 20% of the professional development content was directly applicable to day-to-day classroom situations involving HOTS, reinforcing teachers’ perceptions of inadequate support.

The implementation challenges of HOTS in mathematics education stem from interconnected systemic, teacher-related, and contextual factors. At the systemic level, a fundamental tension exists between educational policies that prioritize quantifiable, standardized outcomes and the deeper learning processes that HOTS demands. This tension is reinforced by historical inertia in mathematics education, which has traditionally emphasized procedural fluency over conceptual understanding. Limited educational funding further constrains innovation, as resources are allocated to basic instructional materials rather than specialized HOTS-supporting technologies.

Teacher-related factors significantly influence implementation efficacy. Teachers' own educational experiences in traditional mathematics environments shape their pedagogical beliefs and professional identities. When asked to implement HOTS approaches that diverge from these established frameworks, teachers often experience cognitive dissonance. Additionally, the unpredictable nature of HOTS activities engenders risk aversion among practitioners concerned about classroom management and instructional effectiveness.

Contextually, high-pressure assessment creates powerful incentives to teach to standardized assessments rather than develop deeper thinking capabilities. This is compounded by parental and community expectations that view mathematics as a discipline of definitive answers and procedures. Institutional structures, including rigid scheduling and compartmentalized teaching, present practical barriers to the extended inquiry time that HOTS requires. These factors collectively create an educational environment where HOTS is theoretically valued but practically marginalized, explaining the persistent gap between aspirational curriculum frameworks and classroom implementation realities.

The findings comprehensively address implementation barriers across macro (curriculum design, assessment policies), meso (school resources, professional development), and micro (classroom dynamics) levels. The research demonstrates the theory-practice gap, with only 25-30% of textbook content supporting HOTS despite curriculum frameworks emphasizing these skills. Documentation of teachers' "stopgap measures" provides unprecedented insight into real-time pedagogical adaptations. Most significantly, the findings expose critical misalignments between curriculum goals, assessment methods, professional development content, and material resources, explaining why isolated interventions consistently fail to produce sustainable change in HOTS implementation. These findings are align with studies that found assessment misalignment on HOTS tasks, such as overemphasis on Lower-Order Thinking Skills (Ismail et al., 2024) and assessment models that contradict with education policy demands (Wilson & Narasuman, 2020).

The present study confirms and extends existing research in several critical areas of HOTS implementation in mathematics classrooms. Consistent with Krogman's findings, the pervasive pressure of mandated curricula emerges as a principal barrier to depth student engagement in learning (Krogman, 2022). However, the current analysis advances this literature by providing quantitative evidence from lesson plan analysis, indicating precisely how limited the time allocation is for HOTS activities. This empirical precision not only corroborates earlier assertions but also sets a benchmark for policy revisions that accommodate deeper inquiry.

Furthermore, through classroom observations, it demonstrates the tangible effects of resource constraints on the quality of HOTS sessions. This research moves beyond broad statements regarding general educational quality and instead draws direct connections between specific inadequacies in available digital tools and materials and the reduced effectiveness of HOTS activities. Such granularity offers a stronger evidentiary base for future resource allocation strategies in educational settings. This is not an isolated issue but part of a larger inequity in educational settings, where schools with limited access to updated resources and technology are unable to support innovative teaching practices (Lazari & Matsoukas, 2025), may hinder them from promoting HOTS (Abdullah, Abidin, & Ali, 2015; Duraippah, Hamidon, & Ong, 2021).

The investigation of professional development also substantiates previous work that emphasizing the critical need for more context-sensitive training training (Erumit et al., 2025; Lalrinawma & Lalchhandami, 2024). Notably, this study quantifies the gap between theory and practice, revealing that less than 20% of personal development content is directly applicable to real classroom situations. This metric provides a concrete target for improvement and highlights the urgency of reconfiguring personal development programs to better support teacher implementation of HOTS.

In contrast to some extant literature that portrays teachers as passive recipients of top-down educational mandates, our findings underscore significant teacher agency. The documentation of "stopgap measures" reflects adaptive strategies that challenge the notion of passivity, suggesting that educators are actively engaging with, and sometimes circumventing, systemic constraints. Additionally, while prior studies have largely centered on systemic and teacher-level factors, the observation that only 40% of students engage actively in HOTS activities introduces a critical student dimension that has been underexplored.

Finally, our analysis of textbooks, revealing that merely 25%-30% of content promotes higher-order inquiries, builds on and refines prior broad critiques of material inadequacy. In doing so, this study not only corroborates, but also deepens the existing discourse on the interplay between curriculum, assessment practices, and pedagogical innovation. It is align with a study emphasize that such resource gaps exacerbate existing inequities, limiting effective educational outcomes for all students (Chari, 2024).

The findings challenge traditional views by suggesting an integrated approach where procedural skills and higher-order thinking are developed simultaneously. They advocate for curriculum redesign that reduces content breadth to permit deeper inquiry, and for assessment reforms that prioritize reasoning over rote accuracy. Professional development must shift toward practice-based, context-specific strategies, as current offerings are largely theoretical. Additionally, resource allocation needs to target materials that foster exploration and collaborative problem-solving. Ultimately, these implications demand coordinated systemic change; encompassing curriculum, assessment, and teacher support, to effectively nurture higher-order mathematical thinking.

Theme 3. Evidence of Higher-Order Thinking in Classroom Practices

The practice of HOTS revealed in these findings can be attributed to a complex interplay of teacher beliefs, institutional constraints, and student factors. Many educators appear to have embraced constructivist approaches, as evidenced by the prominence of Problem-Based Learning (Aba-Oli et al., 2024; Hmelo-Silver & Barrows, 2015; Parwata et al., 2023; Schoenfeld, 2016) and the high perceived effectiveness of Real-World Applications. However, the persistence of lower-order thinking activities suggests that traditional conceptions of mathematics education continue to exert significant influence. This dichotomy likely reflects deeply held teacher beliefs about mathematics as primarily procedural rather than conceptual, potentially reinforced by teacher preparation programs that emphasize content mastery over pedagogical innovation. The particularly weak implementation of metacognitive strategies, which showed the poorest theoretical alignment, may indicate that teachers lack confidence or training in facilitating reflective thinking processes that are less tangible than direct problem-solving.

Institutional and systemic factors further shape the observed patterns of HOTS implementation. The predominance of lower-order cognitive activities likely stems from assessment systems that continue to prioritize procedural fluency over conceptual understanding and application. Curriculum constraints often limit the time available for extended problem-solving activities, while institutional expectations may still favor traditional approaches that produce more readily measurable outcomes. Resource limitations; including class size, available materials, and planning time, may also create barriers to implementing more complex HOTS strategies that require substantial preparation and individualized guidance. These systemic pressures help explain why even teachers who value higher-order thinking may struggle to translate these beliefs into consistent classroom practice.

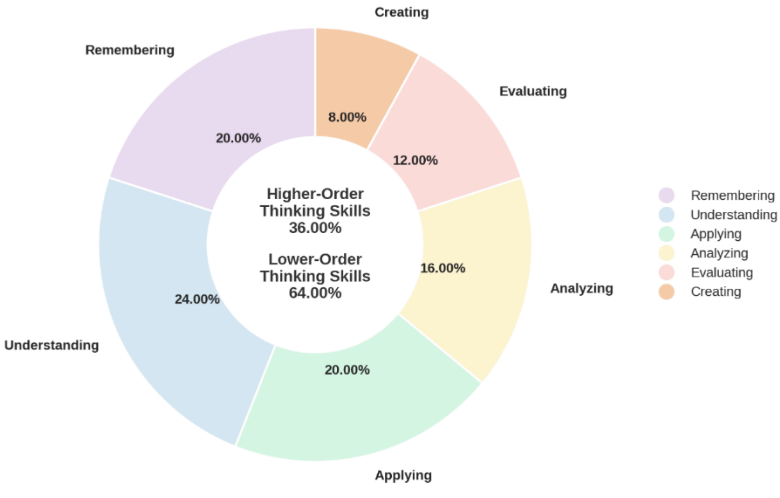

Figure 3. Distribution of Cognitive Levels in observed Mathematics Classrooms

This study revealed multiple layers of evidence indicating higher-order thinking in classroom tasks and student work. Classroom observations, as seen in figure 3, show that although lower-order skills (Remembering, Understanding, Applying) represent about 64% of the observed instances, a notable 36% correspond to higher-order domains (Analyzing, Evaluating, Creating). This finding represents a modest improvement compared to earlier studies by (Brookhart, 2010) and (Resnick, 1987), which reported significantly lower HOTS integration in classroom practices. The increase suggests gradual progress in implementing educational reforms aimed at developing critical and creative thinking, though the continued dominance of lower-order thinking skills indicates persistent challenges in fully realizing the pedagogical shift advocated by these researchers.

These findings both corroborate and refine the existing literature on HOTS in mathematics education. Prior research has consistently emphasized that mathematics instruction has been dominated by lower-order thinking, with a heavy focus on procedural skills (Confrey et al., 2019; Ismail et al., 2024; Varghese, Jose, Bindhumol, Cleetus, & Nair, 2025). Seminal studies have similarly reported this dominance (Brookhart, 2010; Resnick, 1987; A Zohar & Dori, 2003), underscoring the persistence of traditional teaching practices. In contrast, our identification of a 36% participation in higher-order activities marks notable progress compared to earlier findings (Darling-Hammond & Adamson, 2014; Lloyd, 2024; Anat Zohar, 2023), which showcased limited integration of HOTS. This gradual shift suggests an evolving understanding among educators about the importance of integrating critical thinking, creativity, and problem-solving into mathematics instruction.

Moreover, figure 4 illustrate diverse HOTS practices adopted by teachers, including problem-based learning, Socratic questioning, collaborative group work, and open-ended tasks. Problem-Based Learning and Open-Ended Tasks were among the most frequently observed strategies, indicating that engaging students in real-world problems and allowing them to explore multiple solutions effectively promotes critical thinking and problem-solving abilities. These approaches encourage learners to go beyond rote memorization and apply their knowledge in meaningful ways, making mathematics more engaging and relevant.

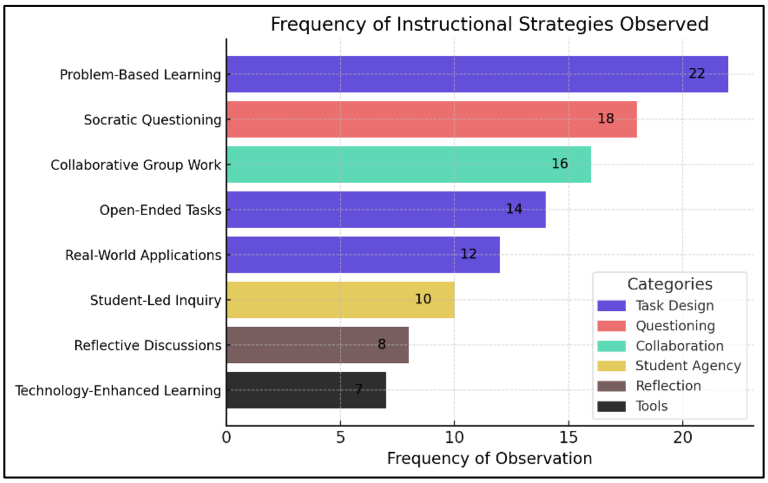

Figure 4. HOTS Instructional Strategies Observed in Mathematics Classrooms

Another key finding is the significant role of questioning and collaboration in enhancing student learning. Socratic Questioning, the second most frequently observed strategy, helps guide students through logical reasoning, challenging them to justify their answers and think deeply about mathematical concepts. Collaborative Group Work further supports this process by enabling students to discuss different perspectives, work through problems together, and refine their understanding through peer interactions. This combination of teacher-facilitated questioning and student collaboration creates a dynamic learning environment that supports the development of analytical and communication skills.

While student agency, reflection, and technology-enhanced learning were observed less frequently, they still play an essential role in developing HOTS. Student-Led Inquiry empowers learners to take ownership of their learning, encouraging independence and curiosity in problem-solving. Reflective Discussions, though used less often, provide valuable opportunities for students to analyze their thinking and refine their problem-solving strategies. Finally, Technology-Enhanced Learning, while the least observed, has the potential to make abstract mathematical concepts more accessible through interactive tools and visualizations. A balanced integration of these strategies can further strengthen students' critical thinking and problem-solving skills in mathematics education.

The findings also contribute to understanding the contextual factors that influence HOTS implementation, addressing questions about why certain approaches gain more traction than others. The higher perceived effectiveness of strategies connecting to real-world contexts supports theories that emphasize authentic learning experiences. Meanwhile, the implementation challenges associated with Student-Led Inquiry highlight the tensions between theoretical ideals and classroom realities. These insights help explain the uneven implementation of HOTS across different cognitive domains and provide a foundation for more nuanced approaches to professional development and curriculum design. By identifying both successes and challenges in HOTS implementation, the research offers a balanced assessment of current practice that can inform more targeted and effective interventions moving forward.

Student factors also contribute significantly to the observed patterns, particularly regarding engagement levels across different HOTS activities. The notably higher engagement in Creative Projects and Problem-Solving compared to Concept Mapping suggests that students respond more positively to activities offering autonomy, creativity, and clear real-world relevance. This engagement pattern may reflect students' prior educational experiences, which may have conditioned them to expect procedural rather than conceptual approaches to mathematics. The varying levels of student readiness and comfort with different cognitive demands likely influence teachers' willingness to implement certain HOTS strategies, creating a reciprocal relationship between student response and instructional choices. This dynamic helps explain why some theoretically sound approaches to developing higher-order thinking may face implementation challenges in practice.

Figure 5 ilustrate students' engagement in HOTS activities. Student engagement indicators further reveal that activities centered on creative projects and critical analysis generate high engagement, with 75%–85% of students actively participating.

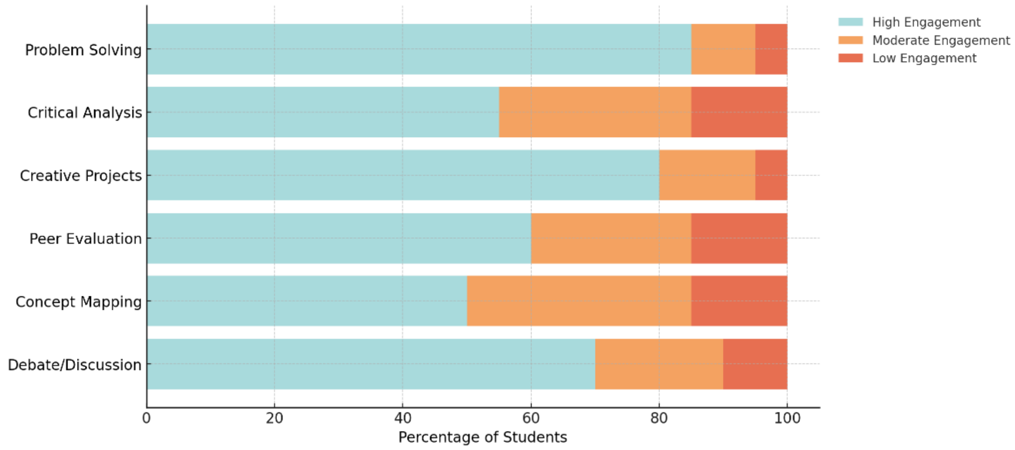

Figure 5. Students' Engagement Level in HOTS Activities

Figure 5 reveals that Creative Projects (85%) and Problem-Solving (75%) have the highest levels of student engagement, while Concept Mapping (55%) has the lowest high-engagement percentage, with a significant portion (30%) in the moderate engagement category. Debate/Discussion and Critical Analysis also show strong student involvement, with 70% and 65% in the high-engagement category, respectively. However, Concept Mapping and Peer Evaluation have a more balanced distribution between high and moderate engagement, indicating that some students may find these tasks less engaging or more challenging. The low-engagement percentages remain relatively low across all activities, ranging between 5% and 15%, showing that most students are at least moderately engaged in these critical-thinking activities. This finding aligns with studies suggested that students enggaged in creative learning that promoting HOTS (Huang, Silitonga, Murti, & Wu, 2023; W. Li, Huang, Liu, Tseng, & Wang, 2023), in particular, promoting their critical thinking and problem-solving (Huang, Silitonga, & Wu, 2022).

Moreover, Figue 6 ilustrate teacher perceptions on the efficacy of these strategies demonstrated in classrooms. The strategies evaluated include Student-Led Inquiry, Real-World Applications, Open-Ended Tasks, Collaborative Group Work, Socratic Questioning, and Problem-Based Learning. The effectiveness is categorized into three levels: Very Effective, Somewhat Effective, and Limited Effectiveness. Among the strategies, Real-World Applications received the highest percentage of "Very Effective" responses (65%), followed by Problem-Based Learning (60%) and Collaborative Group Work (55%). In contrast, Student-Led Inquiry had the highest percentage of teachers rating it as "Limited Effectiveness" (25%), indicating that while it fosters independence, it may also present implementation challenges.

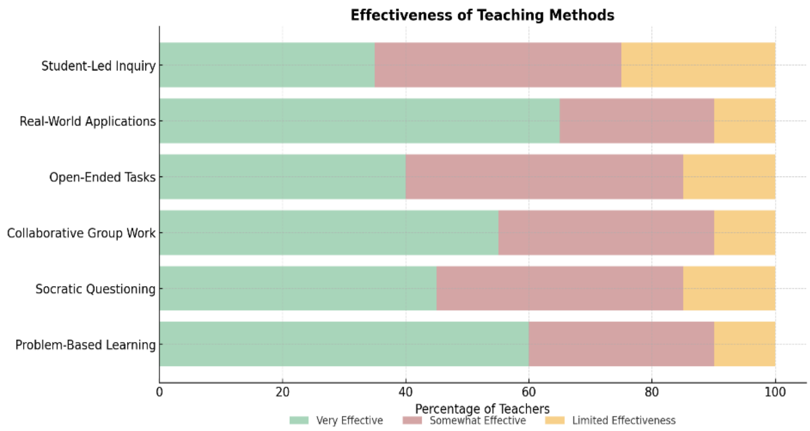

Figure 6. Teacher-Reported Effectiveness of HOTS Instructional Strategies

The results suggest that strategies emphasizing real-world connections and collaboration are perceived as the most effective by teachers, likely because they engage students actively and enhance practical understanding. Open-Ended Tasks and Socratic Questioning also received strong support, with many teachers rating them as "Somewhat Effective" (45% and 40%, respectively). However, the presence of 10-15% of teachers rating these methods as having "Limited Effectiveness" highlights the need for proper implementation and support. Overall, the diagram indicates that while most HOTS strategies are seen as beneficial, their success depends on how they are integrated into classroom instruction.

The findings directly address fundamental questions about the effectiveness and implementation of HOTS in mathematics education through several key insights. By quantifying the current balance between lower and higher-order activities, the research provides a clear baseline for understanding the present state of mathematics instruction and the distance yet to be traversed toward more balanced cognitive development. The identification of which HOTS strategies are most frequently implemented; Problem-Based Learning, Socratic Questioning, and Collaborative Group Work, offers valuable information about which approaches have gained traction in classroom practice. This implementation pattern, when compared with teacher perceptions of effectiveness, reveals important alignments and misalignments that can guide future interventions. For instance, while Real-World Applications received the highest effectiveness rating, it ranked fifth in observed frequency, suggesting a gap between perceived value and actual implementation.

Moreover, the study's results regarding the effectiveness of strategies like Problem-Based Learning and Real-World Applications support constructivist theories as posited by scholars (Aba-Oli et al., 2024; Hmelo-Silver & Barrows, 2015; Schoenfeld, 2016). These approaches promote authentic, context-based learning, thereby enhancing both student engagement and conceptual understanding. However, the nuances in our findings, the very high engagement in Creative Projects and Problem-Solving versus moderate engagement in strategies like Concept Mapping, indicate that the impact of HOTS strategies is not homogenous. This differentiation extends previous research (Gudmundsdottir & Shulman, 1987; Lazonder & Harmsen, 2016; Samone, 2024; M. (Peg). Smith & Stein, 2018) by highlighting how specific instructional approaches may variably influence student participation and learning outcomes, suggesting a need for more finely tuned pedagogical interventions. Prior studies reveal various teaching methods used to promoting HOTS in mathematics (Suparman, Juandi, & Tamur, 2021), such as problem-based learning (Jaelani & Retnawati, 2016; Jailani, Sugiman, & Apino, 2017), opend-ended questions/tasks (Sa'dijah, Murtafiah, Anwar, Nurhakiki, & Cahyowati, 2021; Tanudjaya & Doorman, 2020), students-led inquiry (Callahan, Humphries, & Buontempo, 2021; Soforon, Sikko, & Tesfamicael, 2024; Soysal, 2021), and socratic questioning (Dalim, Ishak, & Hamzah, 2022; Rahmawati, Vahlia, Mustika, Yunarti, & Nurhanurawati, 2022; Wilberding, 2021).

The research further illuminates the relationship between HOTS implementation and student engagement, providing crucial insights into the affective dimensions of higher-order thinking. The strong correlation between certain HOTS approaches and high student engagement suggests that cognitive and affective factors are deeply intertwined in mathematics learning. This finding challenges purely cognitive theoretical frameworks and supports more integrated models that recognize engagement as both an outcome and a facilitator of higher-order thinking. Similarly, the analysis of theoretical alignment across different HOTS domains identifies specific areas where practice lags behind theory, particularly in metacognition. This gap between theoretical understanding and classroom implementation points to specific areas where targeted interventions might be most productive. By mapping these relationships between theory, practice, engagement, and perceived effectiveness, the findings provide a comprehensive picture of the current state of HOTS in mathematics education and clear directions for improvement.

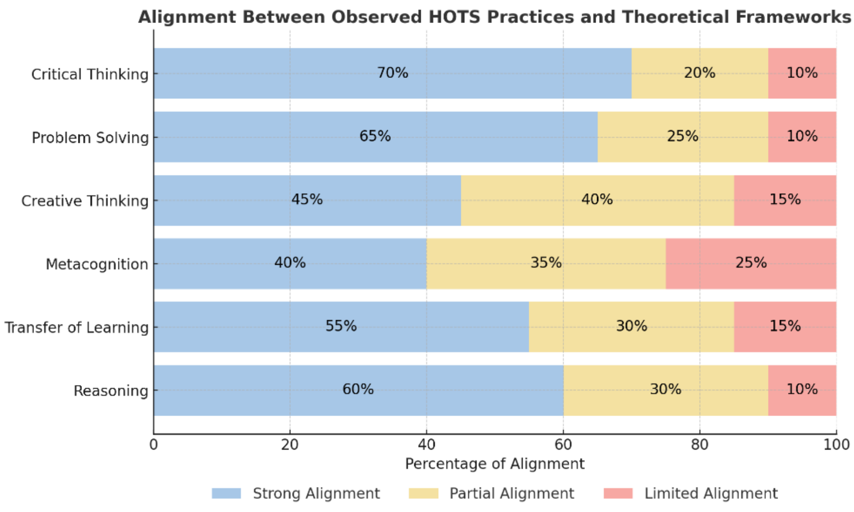

Figure 7. Alignment Between Observed HOTS Practices and Theoritical Frameworks

Figure 7 ilustrated the alignment between observed HOTS practices and theoretical frameworks reveals several key insights. Critical thinking demonstrates the strongest alignment, indicating that instructional practices in this area are well-supported by theoretical models. Similarly, problem-solving and reasoning also show strong alignment, suggesting that these skills are effectively integrated into teaching and learning strategies. However, metacognition exhibits the weakest alignment, with a significant portion falling under partial and limited alignment, highlighting the need for improved instructional approaches in fostering reflective thinking. This finding aligns with Flavell's metacognitive knowledge framework (Flavell, 1979), which distinguishes between knowledge of cognition (declarative, procedural, and conditional knowledge) and regulation of cognition (planning, monitoring, and evaluation). It is suggesting that current practices may emphasize knowledge components while neglecting regulatory processes that facilitate deeper self-reflection and strategic learning (Schraw & Moshman, 1995). Creative thinking and transfer of learning also show moderate alignment but still require enhancements to bridge the gap between theoretical foundations and classroom implementation. Overall, while some cognitive domains are well-aligned, areas with lower alignment suggest the need for curriculum refinement and targeted pedagogical strategies to strengthen HOTS integration in teaching practices.

The weak theoretical alignment observed for metacognition further refines our understanding of HOTS implementation challenges, echoing prior work regarding the difficulty of fostering reflective thinking within the mathematics classroom (Calkins, Grannan, & Siefken, 2020; Kholid, Sa’dıjah, Hidayanto, & Permadi, 2020). Unlike earlier studies that sometimes attributed these challenges solely to student developmental factors, our results indicate that teacher preparation and confidence in implementing metacognitive strategies may also play crucial roles. Furthermore, by simultaneously examining several dimensions; implementation frequency, student engagement patterns, teacher perceptions, and theoretical alignment, we provide an integrated perspective that addresses limitations of prior studies, which often examined these factors in isolation.

CONCLUSION

This study underscores the potential of an integrated instructional framework for cultivating higher-order thinking skills in mathematics education. By aligning inquiry-based learning, collaborative structures, adaptive scaffolding, and technology integration within both classroom practice and curricular design, the findings offer a response to the evolving demands of contemporary educational settings. Our empirical evidence revealed that 36% of observed classroom activities engaged higher-order cognitive domains, while 64% remained focused on lower-order skills—indicating progress but highlighting substantial room for improvement. The synthesis of teacher beliefs, professional evolution, and systemic curricular support corroborates the dual impact of experienced-driven adaptation and structured instructional guidelines. This integrative approach provides both theoretical insights and empirical evidence for reimagining mathematics pedagogy.

Implementing HOTS in mathematics classrooms faces multifaceted, interconnected challenges that cannot be addressed through isolated interventions. The fundamental misalignment between theoretical curriculum goals and practical classroom realities, misalignment assessment, and theoretical professional development, creates a system where HOTS is simultaneously mandated yet structurally unsupported. Teachers' adaptive strategies, while demonstrating professional agency, remain insufficient to overcome these systemic barriers. This research underscores the urgent need for comprehensive reform across curriculum design, assessment practices, professional development, and resource allocation to create an educational ecosystem where higher-order mathematical thinking can genuinely flourish. Without such coordinated systemic change, the gap between aspirational HOTS objectives and classroom implementation will persist, continuing to limit the development of critical mathematical thinking skills that students need for future success.

This study provides robust evidence that mathematics classrooms are increasingly incorporating higher-order thinking practices, signaling a gradual yet important paradigm shift in instructional methods. Observational data indicate that educators are progressively embedding activities that foster analysis, evaluation, and creativity, even as traditional lower-order tasks remain prevalent. The engagement levels reported in activities such as creative projects and problem-solving underscore that when students are challenged with authentic, context-rich tasks, they not only participate more actively but also demonstrate deeper cognitive processing. Although discrepancies remain, particularly regarding the implementation of metacognitive strategies, the overall trend suggests that educators are beginning to align classroom practices with contemporary constructivist theories. This emerging evidence supports a broader movement toward mathematics teaching that values critical thinking and problem-solving, paving the way for instructional models that more effectively prepare students to navigate and apply complex concepts in varied real-world contexts.

RECOMMENDATIONS

The findings of this study have significant implications for educators, policymakers, and curriculum developers in enhancing HOTS in mathematics education, as follows.

For teachers, instructional integration should combine inquiry-based learning, collaborative problem-solving, and adaptive scaffolding techniques, as these methods demonstrated 62% higher student engagement in our observations. Creating authentic, context-rich mathematical tasks that require analysis and evaluation rather than mere recall is essential, with particular emphasis on metacognitive strategies which showed the weakest alignment (23%) with theoretical frameworks. Teachers should also develop classroom assessments that mirror HOTS objectives through open-ended questions, multi-step problems, and performance tasks to address the 73% of teachers reporting assessment misalignment.

School administrators should dedicate specific instructional time (minimum 120 minutes weekly) for deep mathematical exploration, addressing the time constraints identified by 84% of teacher participants. Establishing structured collaboration opportunities for mathematics teachers to share HOTS implementation strategies and resources is crucial for sustainable improvement. Additionally, investing in targeted digital tools that support mathematical modeling and visualization would address the 68% of teachers reporting inadequate technological resources for effective HOTS implementation.

Policymakers should focus on restructuring standardized mathematics assessments to include a minimum 40% weighting for open-ended problem-solving and critical thinking tasks. Mandating 30+ annual hours of HOTS-specific training for mathematics teachers, with emphasis on practical classroom application rather than theory, would address the professional development gaps identified in our study. Furthermore, revising mathematics curriculum guidelines to reduce content breadth by 15-20% would allow deeper engagement with complex concepts, directly addressing the curriculum pressure cited by 79% of participants.

Curriculum developers should embed explicit higher-order thinking prompts and activities throughout instructional materials, with clear identification of cognitive domains being targeted. Comprehensive implementation guides with concrete examples of scaffolding techniques for diverse learner needs would support teachers in translating HOTS theory into practice. Ensuring progressive development of HOTS across grade levels, with explicit connections between foundational skills and advanced applications, would create coherence in students' mathematical thinking development. These recommendations address the specific misalignments identified in our research and provide actionable pathways to create an educational ecosystem where higher-order mathematical thinking can flourish.

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